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...	not applicable
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0^s	value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p}	preliminary
^{r}	revised
x	suppressed to meet the confidentiality requirements of the *Statistics Act*
^{E}	use with caution
F	too unreliable to be published
*	significantly different from reference category ($p < 0.05$)

Cause-specific mortality by income adequacy in Canada: A 16-year follow-up study

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Abstract

Background

People with lower incomes tend to have less favourable health outcomes than do people with higher incomes. Because death registrations in Canada do not contain information about the income of the deceased, vital statistics cannot be used to examine mortality by income at the individual level. However, through record linkage, information on the individual or family income of people followed for mortality can be obtained. Recently, a large, population-based sample of Canadian adults was linked to almost 16 years of mortality data.

Methods

This study examines cause-specific mortality rates by income adequacy among Canadian adults. It is based on data from the 1991 to 2006 Canadian census mortality and cancer follow-up study, which followed 2.7 million people aged 25 or older at baseline, 426,979 of whom died during the 16-year period. Age-standardized mortality rates (ASMRs), rate ratios, rate differences and excess mortality were calculated by income adequacy quintile for various causes of death.

Results

For most causes examined, ASMRs were clearly graded by income: highest among people in the in the lowest income quintile, and lowest among people in the highest income quintile. Inter-quintile rate ratios (quintile 1/quintile 5) were greater than 2.00 for HIV/AIDS, diabetes mellitus, suicide, cancer of the cervix, and causes of death closely associated with smoking and alcohol.

Interpretation

These individually based results provide cause-specific information by income adequacy quintile that was not previously available for Canada.

Keywords

Age-standardized mortality rates, rate ratios, rate differences, socio-economic inequalities

Authors

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Income is a well-established health determinant—people with lower incomes tend to experience less favourable health outcomes, including poorer self-rated health, higher prevalence of disease, and decreased life expectancy, than do people with higher incomes.[1-4] Income influences health most directly through access to material resources such as better quality food and shelter.[5]

Income is also related to exposure to health-promoting (or risky) environments at home and in the workplace, and to the use of facilities and services that influence health, including leisure activities, education, and health services delivered outside Canada's publicly insured health care system.[6-8] Low income in childhood can affect health trajectories into adulthood.[9] The social exclusion, stress, and decreased trust often experienced by lower-income people can also contribute to ill health.[10-12]

Because death registrations in Canada do not contain information about the income of the deceased, vital statistics cannot be used to examine mortality rates by income at the individual level. To overcome this obstacle, several studies have adopted an area-based approach and have demonstrated gradients in mortality by neighbourhood income.[13-17] However, area-based studies used as a proxy for individual-level data typically fail to reveal the full extent of differences in mortality by income that are evident at the individual level.[18] Also, area-based results reflect both the characteristics of the population and the physical and social setting of the geographic areas where people reside.[18]

To overcome limitations with area-based studies, record-linkage-based mortality follow-up studies can be conducted to provide information at the individual level. Recently, a large, population-based sample of Canadian adults who were aged 25 or older at baseline was linked to almost 16 years of mortality data.[19,20] These linked records have been used to examine gradients in all-cause mortality by various socio-economic indicators. Results from the initial 11-year follow-up (1991 to 2001) showed lower all-cause mortality rates in each successively higher socio-economic

level, whether defined by income, education or occupation.[19,21] However, these data have not been used to assess cause-specific variations in mortality by income quintile.

This study examines cause-specific mortality rates by income adequacy quintile, including causes of death grouped by their association with three behavioural risk factors (smoking, alcohol and drugs), and deaths before age 75 that were potentially amenable to medical care.

Methods

Data are from the 1991 to 2006 Canadian census mortality and cancer follow-up study, which tracked mortality in a 15% sample of the 1991 adult population of Canada.[19,20] People were eligible ("in-scope") for the study cohort if they were: 1) aged 25 or older and a usual resident of Canada on the day of the 1991 Census (June 4); 2) not a long-term resident of an institution such as a prison, hospital or nursing home; and 3) selected for census enumeration using the long-form questionnaire, which was administered to one in five private households, and to all residents of non-institutional collective dwellings and Indian reserves. Approximately 3.6 million individuals met these criteria, and thus, were in scope.

The cohort was established via probabilistic matching of 1991 in-scope census records to non-financial tax-filer data from 1990 and 1991, using dates of birth and postal codes of the individual and his/her spouse or common-law partner (if any). About three-quarters of people who were in scope were successfully linked to tax-filer data, creating a cohort of 2.7 million individuals for follow-up in the mortality and cancer incidence data. Earlier analysis revealed that in-scope census respondents who were successfully linked and included in the cohort were slightly younger (less than 65) and more likely to be employed, living in higher-income households, residing in urban areas, and less likely to have changed their place of residence in the previous year.[19]

The cohort was linked to the Canadian Mortality Database (June 4, 1991 to December 31, 2006) using probabilistic methods based mainly on name and date of birth.[22] In the absence of a match to a death registration, follow-up status (alive, dead, emigrated, or lost to follow-up) could be determined using non-financial tax-filer data for 1991 to 2006.[20] Updated analysis (data not shown) demonstrated that life tables constructed from the cohort were similar to Canada life tables for the mid-point of the follow-up period.[19]

Of the 2.7 million cohort members, 426,979 (16%) died during follow-up (Appendix Table A). Mortality data included underlying cause of death, coded according to the *International Classification of Diseases, Ninth Revision*[23] for deaths occurring in 1991 through 1999, and according to the *Tenth Revision*[24] for deaths occurring in 2000 through 2006. Deaths were grouped by Global Burden of Disease categories,[25] and by behavioural health risk factors, namely, smoking-related,[26] alcohol-related[26] and drug-related diseases.[27] Deaths before age 75 that were potentially amenable to medical intervention (for example, due to cerebrovascular disease, hypertension, breast cancer, or pneumonia or influenza[26,28]) were also examined. Appendix Table B contains the corresponding ICD-9 and ICD-10 codes.

To construct income adequacy quintiles, for each economic family or unattached individual, total pre-tax, post-transfer income from all sources was combined across all family members. The ratio of the total income of the economic family to the Statistics Canada low-income cut-off (pre-tax, post-transfer) for the applicable family size and community size group was calculated based on the low-income cut-offs in the 1991 Census Dictionary.[29] All members of a given family (including people living on Indian reserves) were assigned the same low-income cut-off ratio. The in-scope non-institutional population was ranked according to the low-income cut-off ratio, and quintiles of population were constructed within each census metropolitan area, census agglomeration, or rural and small town area (provincial residual). Quintiles were constructed within each area in order to account for regional differences in housing costs, which are not directly reflected in the low-income cut-offs. The percentage of the cohort in each income quintile did not exactly equal 20%, because the quintiles were based on the in-scope population rather than the cohort (which was slightly more affluent).

For each cohort member, person-days of follow-up were calculated from the day of the census (June 4, 1991) to the date of death, emigration, loss to follow-up or end of the study period (December 31, 2006). Person-days of follow-up were divided by 365.25 to obtain person-years at risk. Age-at-baseline-, sex-, and income-quintile-specific mortality rates by five-year age groups were used to calculate age-standardized mortality rates (ASMRs), using the cohort population structure (person-years at risk), both sexes combined, as the standard population. Corresponding 95% confidence intervals for ASMRs were calculated.[30]

Relative inequalities were assessed by rate ratios (RRs) and percent excess mortality. RRs were calculated by dividing the ASMR for those in a lower income quintile (Q1 to Q4) by the ASMR for those in the highest quintile (Q5). RRs greater than 1.00 indicate increased mortality risk. Percent excess mortality was calculated by subtracting the ASMR for those in the highest quintile (Q5) from the ASMR for the total cohort, then dividing by the ASMR for the total cohort and multiplying by 100.

Absolute inequalities were assessed by rate differences (RDs) and absolute excess mortality. RDs were calculated by subtracting the ASMR for those in the highest quintile (Q5) from the ASMR of those in a lower income quintile (Q1 to Q4). RDs greater than 0.0 indicate excess mortality. Absolute excess mortality was calculated by subtracting the ASMR for those in the highest quintile (Q5) from the ASMR for the total cohort. The difference represents the number of deaths

(per 100,000 person-years at risk) that could hypothetically have been avoided if all cohort members had experienced the mortality rates of those in the highest quintile.

Results

For cohort members of both sexes, the ASMRs for all-cause mortality showed a gradient by income adequacy quintile (Table 1). For example, compared with men in the highest quintile, the ASMR rate ratio (RR) was 1.12 (12% higher) for those in the second-highest quintile; 1.21 (21% higher) for those in the middle quintile; 1.35 (35% higher) for those in the second-lowest quintile; and 1.67 (67% higher) for those in the lowest quintile. The pattern was similar for women, among whom RRs were 1.07, 1.14, 1.25, and 1.52, respectively.

The rate difference (RD) between the lowest and highest income quintile was 744 deaths per 100,000 person-years at risk for men and 378 deaths per 100,000 person-years at risk for women. For both sexes, the gap between adjacent quintiles was widest between the lowest and second-lowest quintiles.

Income gradients in mortality emerged for most causes. For men, RRs comparing the lowest with the highest quintiles were greater than 2.00 for deaths due to alcohol use disorders (5.76), HIV/AIDS (3.57), cirrhosis of the liver (2.74), chronic obstructive pulmonary disease (2.73), diabetes mellitus (2.49), cancers of the trachea, bronchus and lung (2.12), and suicide (2.04) (Table 2). No statistically significant income gradient emerged for prostate cancer mortality (1.07).

For women, the RRs comparing those in the lowest with those in the highest income quintile surpassed 2.00 for deaths due to HIV/AIDS (11.13), alcohol use disorders (4.59), cirrhosis of the liver (3.18), diabetes mellitus (2.64), cervix uteri cancer (2.61), chronic obstructive pulmonary disease (2.49), and suicide (2.24) (Table 3). No mortality gradient by income was evident for breast (1.01) and ovarian cancers (1.01).

RDs between the highest and lowest income quintiles were largest for non-communicable diseases (82% of all-cause RD for men and 81% of all-cause RD for women), and smallest for communicable diseases (5% of all-cause RD for both men and women). The major contributors to the RDs among non-communicable diseases were ischemic heart disease; cancers of the trachea, bronchus and lung; and chronic obstructive pulmonary disease.

The last column of Tables 2 and 3 shows income-related excess mortality as a percentage of total mortality. If all cohort members had experienced the ASMRs of those in the highest income quintile, the all-cause ASMR would have been 19% lower for men and 17% lower for women, representing 267 and 144 fewer deaths per 100,000 person-years at risk, respectively. About 40% of this excess mortality was due to deaths from ischemic heart disease, and to cancers of the trachea, bronchus and lung.

Relative and absolute inequalities in mortality by income tended to be high for diseases associated with behavioural risk factors (smoking, alcohol consumption, and drug use). For smoking-related diseases, the RRs were 2.27 for men and 2.02 for women in the lowest income quintile, compared with those in the highest. The corresponding RRs for alcohol- and drug-related diseases (3.81 and 4.31 for men; 3.63 and 5.01 for women) were even higher than for smoking. However, because many more people die from smoking-related diseases, RDs were much larger (179 for men, 73 for women) than for either alcohol-related diseases (27 for men, 9 for women) or drug-related diseases (11 for men, 10 for women).

Deaths before age 75 that were potentially amenable to medical intervention were also considered as a group. The RRs comparing ASMRs of the lowest with the highest income quintiles were 2.52 for men and 1.58 for women. Income-related excess mortality as a percentage of total mortality was 28% for men and 14% for women.

Deaths before age 75 that were not considered potentially amenable to medical intervention were also considered as a group. Here, the RRs comparing the lowest with the highest quintiles were 2.19 for men and 2.20 for women.

Table 1
Age-standardized mortality rates (ASMRs) per 100,000 person-years at risk, rate ratios (RRs) and rate differences (RDs), all causes of death, by sex and income adequacy quintile, non-institutional cohort members aged 25 or older at baseline, Canada, 1991 to 2006

Sex and income quintile	Deaths	ASMR	95% confidence interval		RR	95% confidence interval		RD	95% confidence interval	
			from	to		from	to		from	to
Men										
Quintile 1 (lowest)	52,828	1,850.2	1,834.3	1,866.3	1.67*	1.65	1.70	744.4*	724.3	764.5
Quintile 2	62,137	1,494.4	1,482.3	1,506.6	1.35*	1.33	1.37	388.5*	371.3	405.7
Quintile 3	45,962	1,337.7	1,325.1	1,350.3	1.21*	1.19	1.23	231.8*	214.3	249.3
Quintile 4	40,279	1,236.2	1,223.1	1,249.4	1.12*	1.10	1.14	130.3*	112.4	148.2
Quintile 5 (highest)†	39,781	1,105.9	1,093.8	1,118.1	1.00	...	...	0.0	...	...
Women										
Quintile 1 (lowest)	65,032	1,103.7	1,094.1	1,113.4	1.52*	1.50	1.55	378.4*	364.7	392.1
Quintile 2	43,996	907.8	898.9	916.7	1.25*	1.23	1.27	182.5*	169.3	195.6
Quintile 3	29,015	826.6	817.1	836.2	1.14*	1.12	1.16	101.3*	87.6	114.9
Quintile 4	24,411	772.9	763.1	782.9	1.07*	1.12	1.09	47.6*	33.7	61.5
Quintile 5 (highest)†	23,538	725.3	715.7	735.1	1.00	...	...	0.0	...	...

† reference group (RR = 1.00 and RD = 0.0)
* significantly different from quintile 5 ($p < 0.05$)
... not applicable

Note: Reference population (person-years at risk) for age-standardization was taken from internal cohort age distribution (5-year age group).
Source: 1991 to 2006 Canadian census mortality and cancer follow-up study.

Discussion

The reduction of socio-economic inequalities in health is an explicit objective of health policies in Canada.[2] This study examined detailed cause-specific mortality rates by income adequacy quintile in a large, national, population-based sample.

Gradients in mortality by income for most causes of deaths demonstrated that the association was not confined to those at the lowest end of the income distribution. Each successively lower level of income had a higher mortality rate. The gap between adjacent quintiles was largest between the two lowest quintiles. These results are broadly consistent with other Canadian research.[13-17]

If all cohort members had experienced the age-specific mortality rates of those in the highest quintile, the all-cause ASMRs would have been 19% lower for men and 17% lower for women. Extrapolated to the total non-institutional adult population, that amounts to an estimated 40,000 fewer deaths per year (25,000 fewer among men and 15,000 fewer among women)—the equivalent of eliminating all ischemic heart disease deaths.

The results of this study show that the strength of the association between income and mortality differed by cause

Table 2
Age-standardized mortality rates (ASMRs) per 100,000 person-years at risk for selected causes of death, by income adequacy quintile (Q1 to Q5), male cohort members aged 25 or older at baseline, Canada, 1991 to 2006

	ASMR									
Cause of death	Total	Q1 (lowest)	Q2	Q3	Q4	Q5 (highest)	RR	RD	Excess	% excess
All causes	1,372.8	1,850.2	1,494.4	1,337.7	1,236.2	1105.9	1.67*	744.4*	266.9	19.4
Communicable diseases	57.1	82.5	62.4	54.1	50.7	44.5	1.86*	38.0*	12.7	22.2
HIV/AIDS	5.8	12.7	7.4	4.3	4.4	3.6	3.57*	9.1*	2.2	38.7
Respiratory infections	36.4	47.0	38.8	35.5	33.4	29.2	1.61*	17.8*	7.2	19.8
Non-communicable diseases	1,188.4	1,568.3	1,296.4	1,167.5	1,073.6	959.4	1.63*	608.9*	229.0	19.3
Malignant neoplasms	416.5	510.4	450.1	423.6	386.8	348.6	1.46*	161.8*	67.9	16.3
Stomach cancer	15.5	18.4	18.1	15.2	14.2	12.6	1.46*	5.8*	2.9	19.0
Colon and rectal cancers	44.0	50.0	45.3	45.0	42.5	38.5	1.30*	11.6*	5.5	12.6
Liver cancer	9.0	12.9	9.6	8.7	8.6	7.1	1.80*	5.7*	1.9	21.1
Pancreatic cancer	19.9	20.9	20.5	19.8	19.9	18.7	1.12*	2.2*	1.3	6.4
Trachea, bronchus, and lung cancers	124.1	177.7	147.3	126.2	104.2	83.9	2.12*	93.8*	40.2	32.4
Prostate cancer	51.7	51.6	54.0	53.2	51.0	48.3	1.07	3.3	3.3	6.5
Diabetes mellitus	38.3	61.0	43.0	37.4	33.3	24.5	2.49*	36.6*	13.8	36.0
Neuropsychiatric conditions	65.7	87.0	67.2	62.4	60.8	60.7	1.43*	26.3*	5.0	7.6
Alcohol use disorders	5.0	14.5	4.9	3.7	3.2	2.5	5.76*	12.0*	2.5	49.7
Alzheimer's disease and other dementias	32.9	35.9	34.1	32.4	30.5	32.4	1.11*	3.4*	0.4	1.4
Cardiovascular diseases	483.4	640.2	529.3	467.1	432.9	393.1	1.63*	247.0*	90.3	18.7
Ischemic heart disease	293.3	394.8	323.9	281.6	261.9	233.2	1.69*	161.6*	60.1	20.5
Cerebrovascular disease	79.3	102.6	84.7	78.0	70.8	66.6	1.54*	36.0*	12.6	15.9
Respiratory diseases	86.0	125.3	100.0	82.0	73.9	54.3	2.31*	70.9*	31.7	36.9
Chronic obstructive pulmonary disease	65.4	98.7	78.5	61.7	53.9	36.2	2.73*	62.5*	29.3	44.7
Digestive diseases	46.5	75.7	51.2	43.0	39.5	35.0	2.16*	40.7*	11.5	24.7
Cirrhosis of the liver	15.1	28.9	17.3	13.4	11.7	10.6	2.74*	18.4*	4.5	29.9
Injuries	70.2	108.2	74.4	65.5	64.2	57.6	1.88*	50.7*	12.6	17.9
Unintentional injuries	45.7	68.2	47.6	42.7	42.5	39.6	1.72*	28.6*	6.2	13.5
Road traffic accidents	7.9	11.3	8.1	6.3	7.2	7.8	1.45*	3.5*	0.0	0.5
Intentional injuries	24.4	40.1	26.9	22.8	21.7	18.0	2.23*	22.1*	6.4	26.3
Suicide	22.7	35.1	24.8	21.2	21.2	17.2	2.04*	17.9*	5.5	24.4
Smoking-related diseases	216.2	318.5	254.2	213.0	183.2	140.0	2.27*	178.5*	76.2	35.2
Alcohol-related diseases	15.8	36.9	17.4	13.1	11.3	9.7	3.81*	27.2*	6.2	38.9
Drug-related diseases	5.4	14.8	5.8	4.1	3.6	3.4	4.31*	11.4*	2.1	46.4
Amenable to medical intervention (younger than age 75)	51.6	93.1	59.6	47.3	42.4	36.9	2.52*	56.1*	14.7	28.4
Not amenable to medical intervention (younger than age 75)	518.1	835.8	586.9	507.1	454.5	380.9	2.19*	454.8*	137.2	26.5

* significantly different from rate for quintile 5 ($p < 0.05$)
RR = inter-quintile rate ratio (Q1 / Q5)
RD = inter-quintile rate difference (Q1 - Q5)
Excess = (total - Q5)
% excess = [100 * (total - Q5)/total]
Note: Reference population (person-years at risk) for age-standardization was taken from the internal cohort age distribution (5-year age groups).
Source: 1991 to 2006 Canadian census mortality and cancer follow-up study.

of death, mirroring other research.[31] RRs were highest for causes more closely associated with health risk behaviours (for instance, smoking and excessive alcohol consumption), and lowest or absent for causes not strongly related to those behaviours (such as breast and prostate cancer). This is consistent with research indicating that, compared with people in higher socio-economic categories, those in lower socio-economic categories are more likely to engage in health risk behaviours.[6,32-34] However, risk behaviours do not entirely explain the gradient in health outcomes; other research suggests that socio-economic differences persist even when controlling for behavioural risk factors.[35-37]

A mortality gradient by income was evident for causes that were potentially amenable to medical intervention, a finding consistent with an earlier study examining avoidable mortality by neighbourhood income.[15] Other research has suggested that inequalities in avoidable mortality may be due, in part, to differences in the accessibility, use or quality of medical care,[15,38-40] but the results from this study cannot directly address such issues. For men, the results demonstrated

Table 3
Age-standardized mortality rates (ASMRs) per 100,000 person-years at risk for selected causes of death, by income adequacy quintile (Q1 to Q5), female cohort members aged 25 or older at baseline, Canada, 1991 to 2006

	ASMR									
Cause of death	Total	Q1 (lowest)	Q2	Q3	Q4	Q5 (highest)	RR	RD	Excess	% excess
All causes	869.4	1,103.7	907.8	826.6	772.9	725.3	1.52*	378.4*	144.1	16.6
Communicable diseases	34.2	45.2	35.7	32.0	31.2	27.9	1.62*	17.3*	6.3	18.4
HIV/AIDS	0.5	1.7	0.5	0.3	0.1	0.1	11.13*	1.5*	0.3	69.4
Respiratory infections	21.8	26.6	22.8	20.4	20.3	19.1	1.39*	7.4*	2.7	12.4
Non-communicable diseases	748.0	934.6	781.1	715.6	668.3	629.0	1.49*	305.7*	119.1	15.9
Malignant neoplasms	273.3	316.6	287.9	266.4	258.8	244.0	1.30*	72.6*	29.3	10.7
Stomach cancer	6.8	8.4	7.3	6.6	6.0	5.4	1.56*	3.0*	1.5	21.2
Colon and rectal cancers	28.0	30.1	30.6	27.3	27.2	24.3	1.24*	5.8*	3.7	13.3
Liver cancer	4.3	4.9	4.6	4.3	4.3	3.9	1.28*	1.1*	0.4	9.2
Pancreatic cancer	14.9	15.8	16.0	14.8	15.5	13.1	1.20*	2.6*	1.7	11.8
Trachea, bronchus, and lung cancers	61.7	85.4	66.8	59.9	53.1	46.0	1.86*	39.5*	15.7	25.4
Female breast cancer	49.2	51.3	49.3	48.1	47.5	50.8	1.01	0.5	-1.6	-3.3
Cervix uteri cancer	3.8	6.3	3.9	3.7	3.0	2.4	2.61*	3.9*	1.4	35.7
Ovarian cancer	14.5	14.3	15.2	14.3	14.6	14.1	1.01	0.2	0.3	2.2
Diabetes mellitus	24.3	39.5	25.9	20.8	18.8	15.0	2.64*	24.6*	9.4	38.5
Neuropsychiatric conditions	55.9	65.2	55.9	53.7	53.6	53.6	1.22*	11.6*	2.3	4.2
Alcohol use disorders	1.5	3.4	1.6	1.2	0.8	0.7	4.59*	2.7*	0.7	49.6
Alzheimer's disease and other dementias	36.7	39.0	37.2	34.2	36.5	35.6	1.09*	3.4*	1.0	2.8
Cardiovascular diseases	280.4	352.3	290.8	267.2	242.4	229.8	1.53*	122.6*	50.6	18.1
Ischemic heart disease	142.0	186.4	147.7	133.2	119.1	107.2	1.74*	79.2*	34.8	24.5
Cerebrovascular disease	64.0	75.0	63.7	62.5	59.3	58.7	1.28*	16.3*	5.4	8.4
Respiratory diseases	42.5	62.2	44.3	39.8	35.2	29.5	2.11*	32.7*	13.0	30.5
Chronic obstructive pulmonary disease	30.1	46.1	31.7	27.8	23.4	18.5	2.49*	27.6*	11.5	38.4
Digestive diseases	32.3	47.4	34.7	29.9	26.3	23.3	2.03*	24.1*	9.0	27.9
Cirrhosis of the liver	7.1	13.8	7.4	5.9	5.2	4.4	3.18*	9.5*	2.7	38.6
Injuries	31.2	47.4	31.3	27.7	27.4	25.9	1.83*	21.5*	5.4	17.1
Unintentional injuries	24.4	34.6	24.7	21.8	21.9	20.5	1.69*	14.1*	3.8	15.7
Road traffic accidents	3.5	4.7	3.4	3.4	3.3	3.1	1.51*	1.6*	0.4	11.1
Intentional injuries	6.9	12.8	6.7	5.8	5.5	5.4	2.38*	7.4*	1.5	22.1
Suicide	6.0	11.0	5.7	5.4	4.6	4.9	2.24*	6.1*	1.1	18.7
Smoking-related diseases	100.8	144.7	107.9	96.4	84.1	71.7	2.02*	73.0*	29.1	28.9
Alcohol-related diseases	5.7	12.0	5.7	4.8	4.1	3.3	3.63*	8.7*	2.4	42.4
Drug-related diseases	4.5	12.0	4.3	3.0	2.4	2.4	5.01*	9.6*	2.0	36.9
Amenable to medical intervention (younger than 75)	65.6	89.3	67.4	63.0	58.8	56.4	1.58*	32.9*	9.3	14.1
Not amenable to medical intervention (younger than 75)	254.0	399.1	283.0	237.3	211.6	181.4	2.20*	217.7*	72.6	16.7

* significantly different from rate for quintile 5 ($p < 0.05$)
RR = inter-quintile rate ratio (Q1 / Q5)
RD = inter-quintile rate difference (Q1 - Q5)
Excess = (total - Q5)
% excess = [100 * (total - Q5)/total]
Note: Reference population (person years at risk) for age-standardization was taken from internal cohort age distribution (5-year age groups).
Source: 1991 to 2006 Canadian census mortality and cancer follow-up study.

higher relative mortality for deaths potentially amenable to medical intervention than for those not amenable. The reverse was true among women—relative mortality was higher for deaths not amenable to medical intervention. To some extent, this latter finding may be influenced by breast cancer mortality, a key component of preventable female mortality, which did not show an income gradient.

What is already known on this subject?

- People with lower incomes tend to have less favourable health outcomes than do people with higher incomes.
- Because death registrations in Canada do not contain information about the income of the deceased, vital statistics cannot be used to examine mortality rates by income at the individual level.
- Through record linkage, information on the income of people followed for mortality can be obtained.
- Recently, a large population-based sample of Canadian adults was linked to almost 16 years of mortality data.

What does this study add?

- Data from the 1991 to 2006 Canadian census mortality and cancer follow-up study, which tracked mortality in a 15% sample of the 1991 adult population of Canada, were used to assess cause-specific variations in mortality by income.
- Income gradients in mortality emerged for most causes of death.
- Causes more closely associated with health risk behaviours tended to have particularly steep mortality gradients.

Strengths and limitations

A major strength of this study is the large, population-based sample, which allows for the calculation of mortality differences by income adequacy quintile across a range of cause-of-death groupings, and for the detection of small effects.

Rather than area-based measures, this analysis used individual-level data that more clearly reveal income inequalities in mortality. For example, compared with findings about mortality by neighbourhood income in urban Canada,[13] (special tabulations for 2001, restricted to people aged 25 or older), the inter-quintile RRs for men (and women) in the present study were 22% (39%) higher for ischemic heart disease, 21% (23%) higher for colorectal cancer, 46% (68%) higher for diabetes mellitus, 55% (63%) higher for respiratory diseases, and 53% (70%) higher for road traffic injuries.

To account for some differences in purchasing power by geographic area or other factors,[41] this study defined income quintiles within each census metropolitan area or census agglomeration, instead of using a single set of cut-offs across all regions.

An important limitation is that the income data pertain to cohort inception (1991) and may have changed during the follow-up period (1991 to 2006). Compared with other socio-economic indicators, income varies more often, and its effect on health may accumulate over the life course.[7,41] Measures at a single point in time cannot capture information about income fluctuations over the years.

This study provides baseline individual data on the nature and extent of income-related differences in mortality, but it does not indicate if those differences have persisted, widened or narrowed over time. The analysis was based on the income of cohort members in the year before the 1991 Census. During the follow-up period, the income distribution of Canadians has shifted, with a higher percentage of total income concentrated among a smaller percentage of the population, even after taxes and transfers.[42] This would tend to increase income-related excess mortality, assuming that relative risks remained unchanged.

Analyses based on economic family income assume an equitable distribution of income among family members, which may not necessarily be the case.

Because information on risk factors (such as smoking) that may contribute to mortality was not available, the direct effect of income on mortality might be overestimated. Determining the degree to which individual behaviours and risk factors explain (or fail to explain) the higher mortality rates among people in lower income quintiles would require long-term mortality follow-up from health surveys that collect data on behavioural risk factors and on socio-economic indicators.

Conclusion

Mortality rates differ by level of income for most causes of death. Causes more closely associated with health risk behaviours tend to have particularly steep mortality gradients. These results build on previous research by providing evidence by cause-specific groups, and confirm the existence of a consistent gradient in mortality by income across most causes of death. ■

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Appendix

Table A
Cohort members, person-years at risk, and deaths ascertained, by sex and income adequacy quintile, cohort members aged 25 or older at baseline, Canada, 1991 to 2006

Sex and income quintile	Cohort members	Person-years at risk	Number of deaths
Men			
Quintile 1 (lowest)	197,300	2,555,390	52,828
Quintile 2	260,800	3,499,990	62,137
Quintile 3	287,700	4,077,240	45,962
Quintile 4	302,600	4,359,170	40,279
Quintile 5 (highest)	309,900	4,476,770	39,781
Women			
Quintile 1 (lowest)	273,000	3,681,630	65,032
Quintile 2	270,300	3,826,020	43,996
Quintile 3	277,600	4,056,340	29,015
Quintile 4	278,200	4,105,330	24,411
Quintile 5 (highest)	277,500	4,104,200	23,538

Source: 1991 to 2006 Canadian census mortality and cancer follow-up study.

Table B
ICD-9 and ICD-10 codes for causes of death

Cause of death	ICD-9	ICD-10
Communicable diseases	001–139, 243, 260– 269.279.5, 280–281, 285.9, 320-323, 381–382, 460–465, 466, 480-487, 614–616, 630–676, 760-779	A00-B99, G00-G04, N70-N73, J00-J06, J10-J18, J20-J22, H65-H66, O00-O99, P00-P96, E00-E02, E40-E46, E50, D50-D53, D64.9, E51-E64,
HIV/AIDS	042-044, 279.5	B20-B24
Respiratory infections	460-466, 480-487, 381-382	J00-J06, J10-J18, J20-J22, H65-H66
Non-communicable diseases	140–242, 244–259, 270-279 (minus 279.5), 282-285 (minus 279.5), 286–319, 324-380, 383–459, 470–478, 490-611, 617–629, 680-759	C00-C97, D00–D48, D55-D64 (minus D 64.9), D65–D89, E03-E07, E10-E16, E20-E34, E65-E88, F01-F99, G06-G98, H00-H61, H68-H93, I00-I99, J30-J98, K00-K92, N00-N64, N75-N98, L00-L98, M00-M99, Q00-Q99,
Malignant neoplasms	140-208	C00-C97
Stomach cancer	151	C16
Colon and rectal cancers	153-154	C18-C21
Liver cancer	155	C22
Pancreatic cancer	157	C25
Trachea, bronchus and lung cancers	162	C33-C34
Female breast cancer	174-175	C50
Cervix uteri cancer	180	C53
Ovarian cancer	183	C56
Prostate cancer	185	C61
Diabetes mellitus	250	E10-E14
Neuropsychiatric conditions	290-319, 324-359	F01-F99, G06-G98
Alcohol use disorders	291, 303, 305.0	F10
Alzheimer's disease and other dementias	290, 330, 331	F01, F03, G30-G31
Cardiovascular diseases	390-459	I00-I99
Ischemic heart disease	410-414	I20-I25
Cerebrovascular disease	430-438	I60-I69
Respiratory diseases	470-478, 490-519	J30-J98
Chronic obstructive pulmonary disease	490-492, 495-496	J40-J44
Digestive diseases	530-579	K20-K92
Cirrhosis of the liver	571	K70, K74
Injuries	E800-999	V01–Y89
Unintentional injuries	E800-949	V01-X59, Y40-Y86, Y88, Y89
Road traffic accidents	E810-819, E826-829, E929.0	† See note
Intentional injuries	E950–-978, 990-999	X60-Y09, Y35-Y36, Y870, Y871
Suicide	E950-959	X60-X84, Y870
Intent of injury not known	E980-E989	Y10-Y34, Y872
Smoking-related diseases	140-150, 161-163, 165, 490-494, 496	C00-C15, C30-C34, C39, J40-J44, J47
Alcohol-related diseases	291, 303, 3050, 4255, 571.0-571.3, 577.0-577.1, 860	F10, I426, K70, K85, K86.0, X45
Drug-related diseases	292, 304, 305.2-305.9, 850-858, 950.0-950.5, 980.0, 980.5, 962.0	F11-F16, F18, F19, X40-X44, X60-X64, X85, Y10-Y14
Deaths amenable to medical intervention	001-139, 174-175, 180, 201, 204-208, 401-405, 430-438, 480-487, 531-534, 540-543, 550-553, 560, 574-576, 630-677	A00-B99, U04, C50, C53, C81, C91-C95, I10-I15, I60-I69, J10-J18, K25-K28, K35-K38, K40-K46, K56, K80-K83

† **Note:** V01.1–V01.9, V02.1–V02.9, V03.1–V03.9, V04.1–V04.9, V06.1–V06.9, V09.2, V09.3, V10.4–V10.9, V11.4–V11.9, V12.3–V12.9, V13.3–V13.9, V14.3–V14.9, V15.4–V15.9, V16.4–V16.9, V17.4–V17.9, V18.4–V18.9, V19.4–V19.6, V20.3–V20.9, V21.3–V21.9, V22.3–V22.9, V23.3–V23.9, V24.3–V24.9, V25.3–V25.9, V26.3–V26.9, V27.3–V27.9, V28.3–V28.9, V29.4–V29.9, V30.4.V30.9, V31.4–V31.9, V32.4–V32.9, V33.4–V33.9, V34.4–V34.9, V35.4–V35.9, V36.4–V36.9, V37.4–V37.9, V38.4–V38.9, V39.4–V39.9, V40.4–V40.9, V41.4–V41.9, V42.4–V42.9, V43.4–V43.9, V44.4–V44.9, V45.4–V45.9, V46.4–V46.9, V47.4–V47.9, V48.4–V48.9, V49.4–V49.9, V50.4–V50.9, V51.4–V51.9, V52.4–V52.9, V53.4–V53.9, V54.4–V54.9, V55.4–V55.9, V56.4–V56.9, V57.4–V57.9, V58.4–V58.9, V59.4–V59.9, V60.4–V60.9, V61.4–V61.9, V62.4–V62.9, V63.4–V63.9, V78.4–V78.9, V79.4–V79.9, V80.3–V80.5, V81.1, V82.1, V83.0–V83.3, V84.0–V84.3, V85.0–V85.3, V86.0–V86.3, V87.0–V87.8, V89.2, V89.9, V99, Y850.